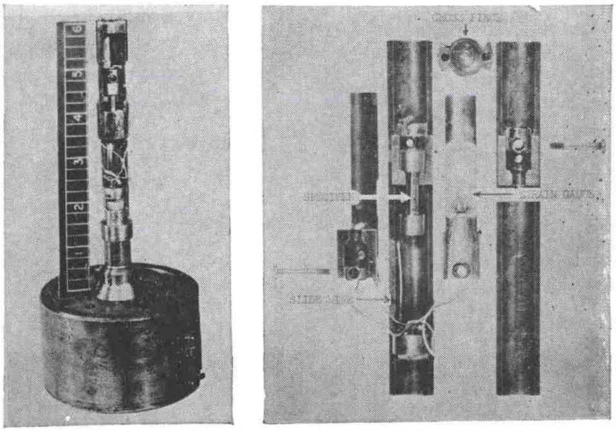

FIG. 1. High pressure tensile test fixture.

RESULTS

Effect of pressure on ductility and fracture appearance

The effects of pressure on the various materials examined is summarized in the pressure versus reduction in area plots shown in Figs. 2(a–e). For simplicity, each of the materials will be separately considered.

Pure bismuth

The effect of superimposed pressure upon the tensile ductility of pure bismuth is shown in Fig. 2(a), along with the data of Pugh.(4) It should be noted that a sharp ductility transition is observed for this material at a particular pressure which will be defined as the Brittle to Ductile Transition Pressure (BDTP) and will correspond to the lowest pressure

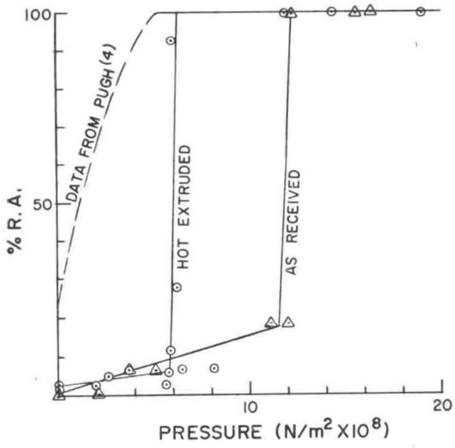

FIGURE 2A

FIG. 2(a). Pressure–ductility curve for 100% Bi, comparing results for columnar (as cast) and equiaxed (extruded) microstructures to data derived from results reported by Pugh.(4)

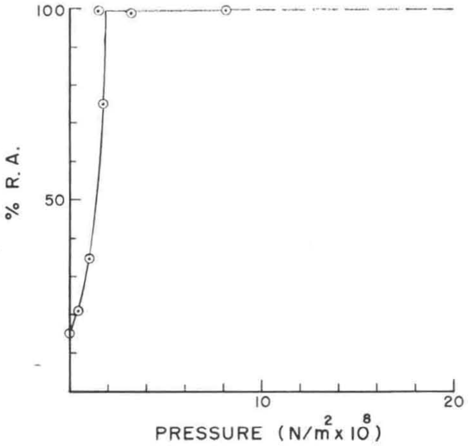

FIG. 2(b). Pressure–ductility curve for a 90% Sn–bal Bi alloy.

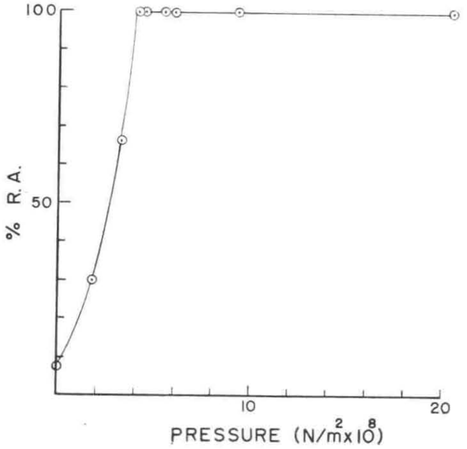

FIG. 2(c). Pressure–ductility curve for a 75% Sn–bal Bi alloy.

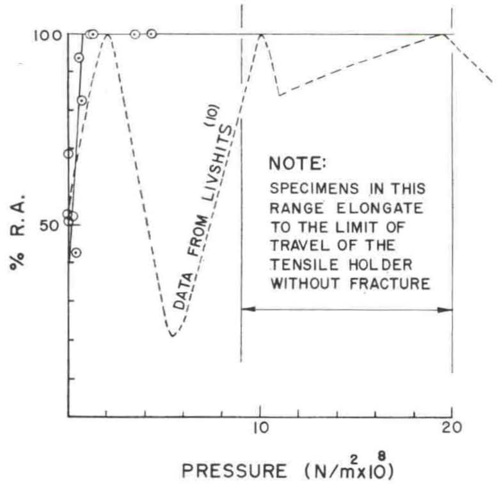

FIG. 2(d). Pressure–ductility curve for a 42% SN-bal Bi alloy. Results derived from data reported by Livshits *et al.*(10) are shown for comparison.

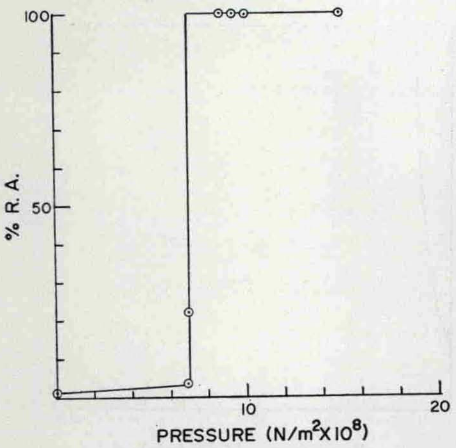

FIG. 2(e). Pressure–ductility curve for a 9% Sn–bal Bi alloy.

resulting in virtually 100 per cent reduction in area. It should be noted that the BDTP is highly structure sensitive. The BDTP was observed to be approximately 6×10^8N/m^2 (6 kb-) when the structure consisted of equiaxed grains with an average grain boundary intercept distance of 0.33 mm. However, when the material was in the as-cast condition the BDTP was observed to be approximately 11.5×10^8N/m^2 (11.5 kb). In addition to being cast, this material had a significantly larger grain size, the average grain size being as much as one-half the specimen diameter or approximately 1.15 mm in some areas of the specimen. Referring to Figs. 3 and 4(a), the fracture mode below the transition pressure is transgranular cleavage. Numerous stable microcracks are present behind the fracture surface of a tensile specimen fractured at atmospheric pressure and the number of mechanical twins increased as the fracture surface is approached (Fig. 4b). As can be seen by comparing Fig. 7(a) with 7(b), the macroscopic fracture mode changes with pressure from a flat crystalline type to ductile rupture.

Careful examination of the region in the vicinity of the tensile fracture surface revealed that the predominant mechanism of crack nucleation was the intersection of twins with grain boundaries as seen in Figs. 5(a) and (b). Although the predominant crack in Fig. 5(b) is not apparently associated with a twin-grain boundary interaction, this is simply a manifestation of the polished surface not intersecting the point of crack nucleation as is schematically shown in Fig. 6.

Increasing the level of superimposed pressure towards the BDTP results in a small increase in ductility. The resultant mechanical twin density is increased, but there is a decrease in the number of microcracks

FIG. 3. The appearance of the fracture surface of a pure bismuth specimen which fractured at 5.0×10^8 N/m^2. 3250 ×

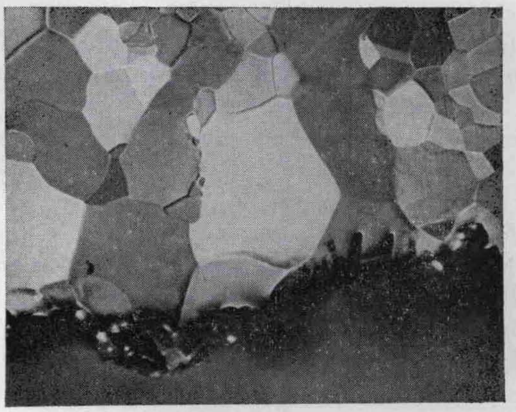

FIG. 4(a). The microstructure of pure bismuth specimens tested to failure at atmospheric pressure. 50 ×, Unetched, Polarized Light.

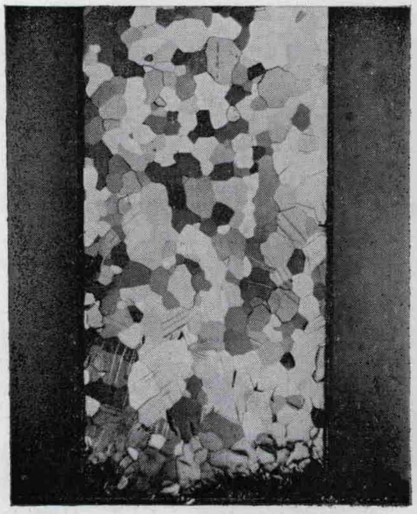

FIG. 4(b). The microstructure of pure bismuth specimens tested to failure at atmospheric pressure, 15 ×. Unetched, Polarized Light.